UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

IRRIGATION INVESTIGATIONS WITH FIELD CROPS AT DAVIS, AND AT DELHI, CALIFORNIA 1909-1925

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(Based on data gathered in cooperation with the Division of Agricultural Engineering, Bureau of Public Roads, U. S. Department of Agriculture, and the Division of Engineering and Irrigation, California State Department of Public Works.)

BULLETIN 450

MARCH, 1928

UNIVERSITY OF CALIFORNIA PRINTING OFFICE
BERKELEY, CALIFORNIA
1928

IRRIGATION INVESTIGATIONS WITH FIELD CROPS AT DAVIS, AND AT DELHI, CALIFORNIA, 1909-1925[1]

S. H. BECKETT[2] AND MARTIN R. HUBERTY[3]

This bulletin reports the results of certain irrigation experiments with field crops in the Sacramento and San Joaquin valleys. The work, as originally planned, was limited to the irrigation tract of the University Farm, at Davis, the purpose being to determine the duty of water for alfalfa and field crops and the methods of applying the water to obtain maximum returns. In 1922, as a part of the cooperative investigations, alfalfa studies were also undertaken on the irrigation experimental tract at Delhi, in the San Joaquin Valley.

INVESTIGATIONS WITH ALFALFA AT THE UNIVERSITY FARM AND AT DELHI

In 1907, a tract of twenty-five acres was set aside. Experiments were started in 1909. The planting of experimental orchards and vineyards on the tract in 1915 and 1917 necessitated a rearrangement of the fields, making it impossible to maintain a uniform system of plot numbering throughout the sixteen years covered. Figures 1 and 2 show the general arrangement of plots during the periods 1911–1915 and 1915–1925.

The soil of the tract is described as a Yolo fine sandy loam of medium texture to a depth of 18 to 20 feet, having a maximum soil moisture 'field capacity' of 20 to 22 per cent. At no time during the investigations was the underground water table closer than 14 feet from the surface. From time to time, attempts were made to obtain information on the use of water by means of intensive soil sampling. Variability of the soil made it impossible, however, to secure reliable results by that method. The experiments were limited, therefore, to a study of yields under different irrigation treatments.

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[1] Results of the investigations have been, in part, previously published in U. S. Department of Agriculture Bulletin 10, California State Department of Engineering Bulletin 3, California Agricultural Experiment Station Bulletin 280, and biennial reports of the State Engineer of California and the Director of the California Agricultural Experiment Station.

The work at Davis reported herein has been conducted by the authors; that at Delhi mainly by Martin R. Huberty and Frank Davis, Junior Irrigation Engineer, Division of Irrigation Investigations and Practice.

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The water supply was obtained by pumping, a storage reservoir of one-quarter acre-foot capacity being used to regulate the flow. Delivery of water from the pump and the reservoir to the various field ditches and plots was made through a concrete pipe system.

All water used in the experiments was measured by means either of rectangular weirs located in weir boxes in the pipe lines, or by temporary weirs installed in the field laterals.

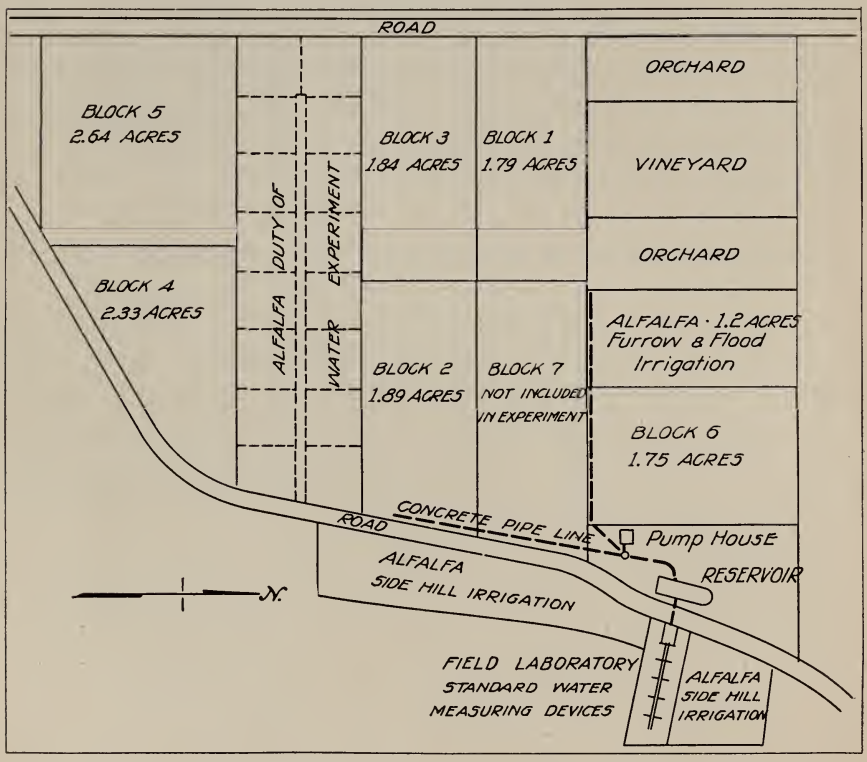

Fig. 1.—Experimental irrigation tract, University Farm, Davis, California, showing areas included in investigations, 1912–1915.

Standard practices for the localities were followed in the preparation of land for irrigation, in the preparation of seed bed, and in irrigation, cultivation, and harvesting. The time to irrigate was determined by examination of the moisture condition of the soil and by the appearance of the crop, an attempt being made to secure maximum yields under the various treatments.

In 1920, a tract of forty acres was leased from the State Land Settlement Board at Delhi, California, to be used in cooperative irri-

gation investigations. The soil of the tract is described as an Oakley fine sand, ranging in depth from 6 to 9 feet. The maximum 'field capacity' ranges from 6 per cent at the surface to 10 per cent and 12 per cent at the lower depths. A tough calcareous hardpan, light gray in color, 10 to 12 inches in thickness and practically impervious to water, underlies the whole area at depths of 6 to 9 feet.

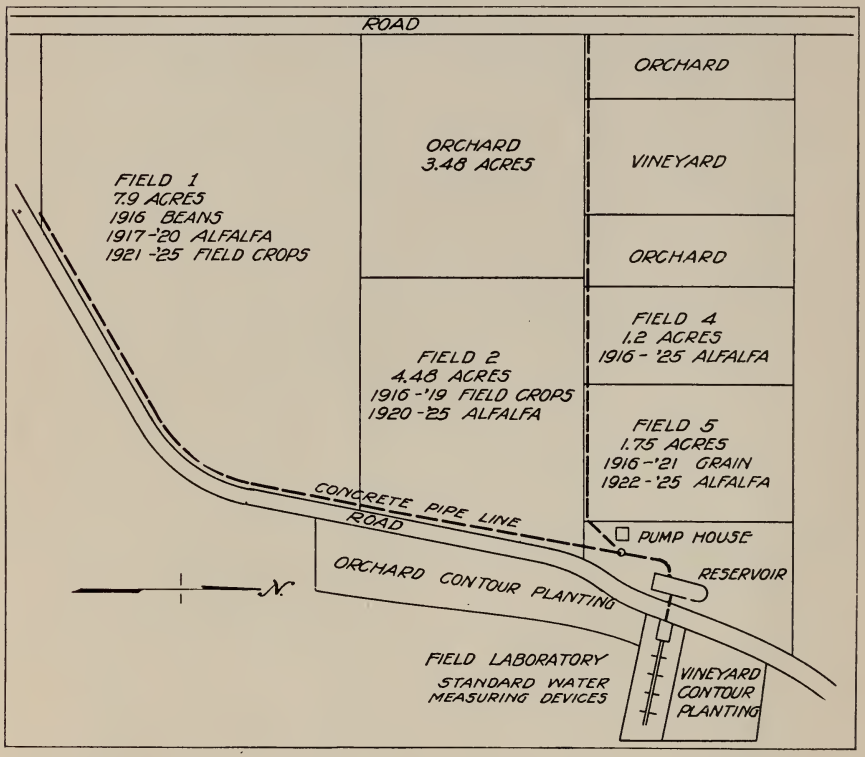

Fig. 2.—Experimental irrigation tract, University Farm, Davis, California, showing areas included in investigations, 1916–1925.

Water for irrigation was obtained by pumping, distribution being made to the entire area through a concrete pipe system. Water applied was measured by rectangular weirs placed in the distributing system. Figure 3 shows the arrangement of the plots with the irrigation schedule followed from 1922 to 1925.

The land was prepared for irrigation in the winter of 1920 and seeded to alfalfa in the spring of 1921. During 1921, there was no variation in irrigation treatment, sufficient water being applied during the season to produce normal growth.

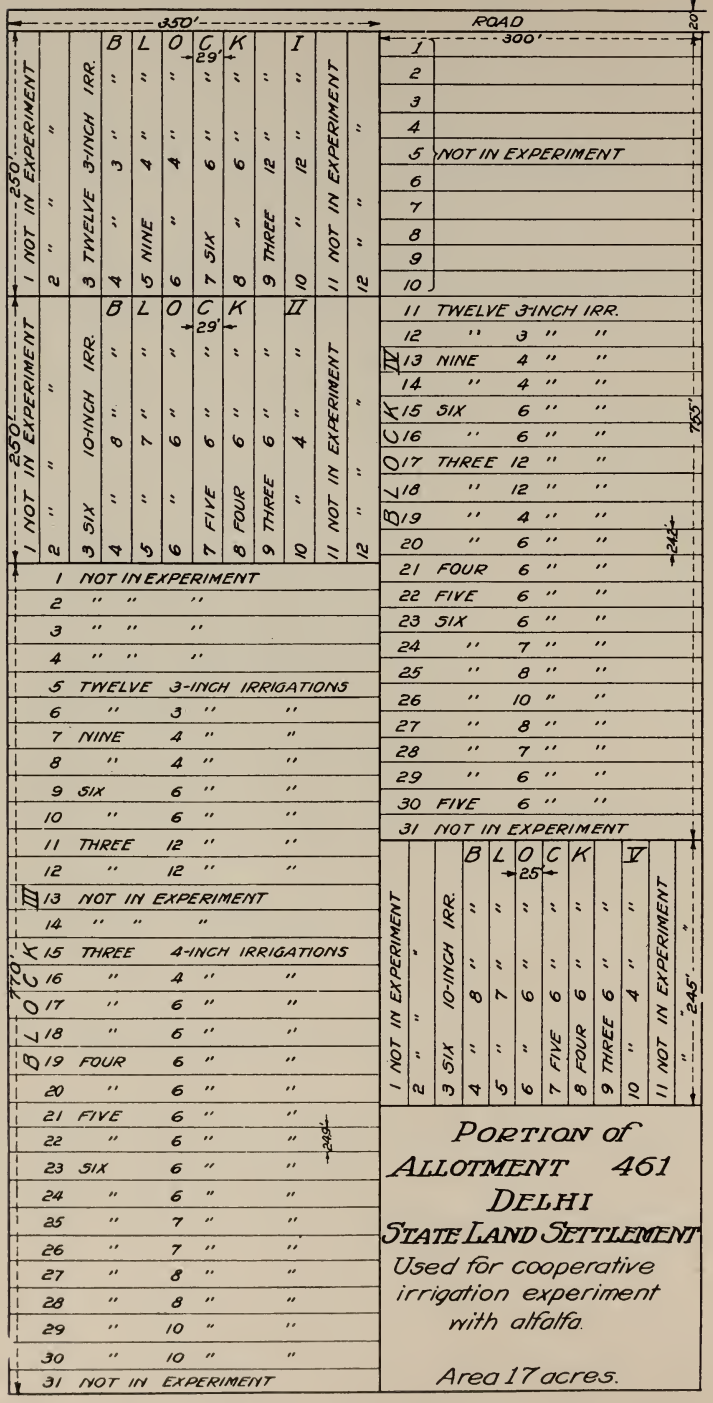

Fig. 3.—Portion of irrigation experimental tract, Delhi, California, showing arrangement and location of alfalfa checks.

Irrigation of Alfalfa at Davis, 1910–1915,[4] *1918–1925; and at Delhi, 1922–1925.*—The treatments in the irrigation of alfalfa for the periods indicated above are summarized in tables 1 and 2; the results of the experiments, except as elsewhere previously reported, are given in tables 3, 4, and 5.

TABLE 1

IRRIGATION TREATMENT AT DAVIS

Experiments with various depths of water applied, 1910–1915			Experiments with constant depth of water applied but variable number of irrigations, 1918–1925		
Number of irrigations	Unit depth of irrigation, *inches*	Total seasonal depth water applied, *inches*	Number of irrigations	Unit depth of irrigation, *inches*	Total seasonal depth water applied, *inches*
None	.....	.....	2	15	30
2	6	12	3	10	30
3	6	18	4	7½	30
4	6	24	6	5	30
4	7½	30	8	3¾	30
4	9	36	12	2½	30
4	12	48	.....	.....	.....
4	15	60	.....	.....	.....

TABLE 2

IRRIGATION TREATMENT AT DELHI

Experiments with various depths of water applied, 1922–1924			Experiments with constant depth of water applied but variable number of irrigations, 1922–1924		
Number of irrigations	Unit depth of irrigation, *inches*	Total seasonal depth water applied, *inches*	Number of irrigations	Unit depth of irrigation, *inches*	Total seasonal depth water applied, *inches*
3	4	12	3	12	36
3	6	18	6	6	36
4	6	24	9	4	36
5	6	30	12	3	36
6	6	36	....	....	....
6	7	42	....	....	....
6	8	48	....	....	....
6	10	60	....	....	....
Season of 1925					
4	6	24	....	....	....
6	6	36	....	....	....
8	6	48	....	....	....

[4] The results of these experiments are reported in detail in: Beckett, S. H., and R. D. Robertson. The economical irrigation of alfalfa in the Sacramento Valley, California. Agr. Exp. Sta. Bul. 280:271–294. 1917. Adams, Frank, *et al.* Investigations of the economical duty of water for alfalfa in Sacramento Valley, California, 1910–1915. State Dept. Engineering Bul. 3:6–13. 1917.

TABLE 3

YIELDS OF ALFALFA PLOTS WITH SEASONAL DEPTH CONSTANT BUT WITH VARYING NUMBERS AND DEPTHS OF IRRIGATIONS, DAVIS, 1918–1925

Field	Block	Number of plots	Acre	Number of irrigations	Depth of each irrigation, *inches*	Total seasonal depth of irrigation, *inches*	Yield, *tons to the acre*					
							1918	1919	1920	1921	Average	Avg. 9 yrs.*
I	2	3	0.61	2	15	30	7.84	9.66	8.35	6.64	8.12	8.24
	2	3	0.61	3	10	30	7.12	10.60	8.30	8.22	8.56	8.41
	2	3	0.61	4	7½	30	7.28	10.09	6.88	7.13	7.85	7.57
	2	3	0.61	6	5	30	8.00	10.85	7.48	9.07	8.85	8.72
	3	3	0.59	8	3¾	30	8.90	11.16	8.07	8.60	9.18	8.79
	3	3	0.54	12	2½	30	10.21	11.06	9.09	8.42	9.70	9.42
							1921	1922	1923	1924	1925	Avg.
II	2	4	0.68	2	15	30	8.25	8.03	7.80	8.19	9.36	8.33
	2	4	0.68	3	10	30	7.70	8.61	8.50	8.24	8.42	8.29
	2	4	0.68	4	7½	30	6.99	7.22	7.15	7.36	8.07	7.36
	3	4	0.82	6	5	30	8.16	7.92	8.16	9.15	9.65	8.61
	3	4	0.77	8	3¾	30	8.43	8.42	8.42	7.58	9.49	8.47
	3	4	0.71	12	2½	30	9.15	9.75	8.75	8.55	9.80	9.20

* Average of four-year trials on field I and five-year trials on field II.

TABLE 4

SUMMARY OF RESULTS OF ALFALFA DUTY-OF-WATER EXPERIMENTS, DELHI, CALIFORNIA, 1922–1924

Number of plots	Acres	Unit depth each irrigation, *inches*	Total seasonal depth of water applied, *inches*	Yield, *tons to the acre*				Average value of hay per acre*	Average cost of production per acre†	Average profit per acre
				1922	1923	1924	Average			
5	0.875	4	12	7.04	4.98	3.79	5.27	$58.00	$24.08	$33.92
3	0.475	6	18	7.82	5.23	4.00	5.68	62.48	27.22	35.26
5	0.875	6	24	8.60	5.51	4.63	6.25	68.75	31.00	37.75
6	1.040	6	30	8.63	6.37	6.62	7.21	79.30	36.34	42.96
6	1.040	6	36	9.23	7.36	8.02	8.20	90.20	41.80	48.40
6	1.040	7	42	9.65	8.07	8.42	8.71	95.80	45.34	50.46
6	1.040	8	48	8.95	7.77	8.53	8.42	92.60	45.68	46.92
5	0.875	10	60	8.68	7.46	8.57	8.24	90.65	47.96	42.69
				Season of 1925						
28	4.8	6	24	6.63	.....	.....	.....	.....	.....	.....
30	5.2	6	36	7.15	.....	.....	.....	.....	.....	.....
23	4.6	8	48	6.45	.....	.....	.....	.....	.....	.....

* Figured at $11 a ton in the stack.

† Cost of water figured at $1.50 an acre-foot; labor of irrigation at 12½ cents an acre-inch; cutting, raking, shocking, and handling at $4 a ton.

The comparison of yields under varying irrigation treatments at Davis and at Delhi is made graphically in figures 4 and 5.

TABLE 5

YIELDS OF ALFALFA PLOTS WITH SEASONAL DEPTH CONSTANT BUT WITH VARYING NUMBERS AND DEPTHS OF IRRIGATIONS, DELHI, 1922–1924

Number of plots	Acres	Number of irrigations	Depth of each irrigation, *inches*	Total depth of irrigation, *inches*	Yield, tons to the acre			
					1922	1923	1924	Average
6	1.07	3	12	36	7.29	7.00	6.05	6.78
6	1.07	6	6	36	7.89	7.00	6.85	7.25
6	1.07	9	4	36	7.70	7.40	7.46	7.52
6	1.07	12	3	36	7.06	6.69	7.57	7.11

The Effect of the Amount and Frequency of Irrigation on the Root Development of Alfalfa.—At the conclusion of the experiments at Davis and at Delhi, in which a constant seasonal depth of water had been applied in varying amounts and frequencies of time, observations were made to determine the effect of these treatments on the root development of the alfalfa.

At a point near the center of a representative plot of each treatment, an area 3 by 5 feet was selected under conditions of uniform stand and where examination showed the soil to be of uniform type.

A templet with inside dimensions of 3 by 5 feet was fastened to the ground surface. All plants within this area were trimmed to a stem length of one inch above the crown, the number of plants then counted, and cut off at a point immediately below the crown.

It was originally planned to remove the soil in layers and by washing through screens, to separate the roots so their weights could be obtained. It was found, however, that the gravel contained in the soil fouled the finer screens to such an extent that no progress could be made. The dry soil was therefore removed, pulverized and then passed through a ⅛-inch-mesh screen, and the roots separated by hand.

Tables 6 and 7 show the dry weights of roots obtained and their distribution in percentage of total weight taken from a 6-foot depth.

Figures 6 and 7 show the root distribution under varying irrigation treatments at Davis and Delhi.

TABLE 6

ROOT DISTRIBUTION UNDER VARYING IRRIGATION TREATMENTS AT DAVIS

Depth, *inches*	Twelve 2½-inch irrigations		Eight 3¾-inch irrigations		Six 5-inch irrigations		Four 7½-inch irrigations		Three 10-inch irrigations		Two 15-inch irrigations	
	Dry wt., *grams*	Per cent of total	Dry wt., *grams*	Per cent of total	Dry wt., *grams*	Per cent of total	Dry wt., *grams*	Per cent of total	Dry wt., *grams*	Per cent of total	Dry wt., *grams*	Per cent of total
Crowns	390.7	.....	460.1	.....	407.6	.....	410.0	.....	577.8	.....	415.9	.....
0– 6	238.4	33.0	338.0	42.3	340.7	37.2	256.6	33.2	290.0	34.0	342.3	35.7
6–12	102.6	14.2	121.8	15.2	146.0	15.9	113.0	14.6	157.6	18.5	149.7	15.6
12–18	86.6	11.9	81.1	10.1	115.5	12.6	86.5	11.2	88.2	10.3	112.7	11.8
18–24	61.7	8.5	64.3	8.1	62.0	6.8	63.0	8.2	73.2	8.6	78.4	8.2
24–30	54.2	7.5	42.0	5.3	63.0	6.9	53.3	7.0	52.7	6.2	48.4	5.0
30–36	45.8	6.3	38.4	4.8	44.4	4.8	41.9	5.4	50.9	6.0	41.6	4.3
36–42	34.8	4.8	31.1	3.9	40.0	4.4	37.2	4.8	35.4	4.1	34.2	3.6
42–48	28.1	3.9	18.1	2.3	27.3	3.0	30.3	3.9	26.2	3.0	41.8	4.4
48–54	22.4	3.1	19.9	2.5	24.3	2.6	25.3	3.3	26.4	3.1	29.0	3.1
54–60	19.2	2.7	17.3	2.2	21.3	2.3	25.1	3.3	20.1	2.4	32.0	3.3
60–66	17.2	2.4	14.4	1.8	15.9	1.8	19.0	2.5	15.5	1.8	26.3	2.8
66–72	11.8	1.6	12.2	1.5	15.3	1.7	20.2	2.6	17.2	2.0	21.5	2.2

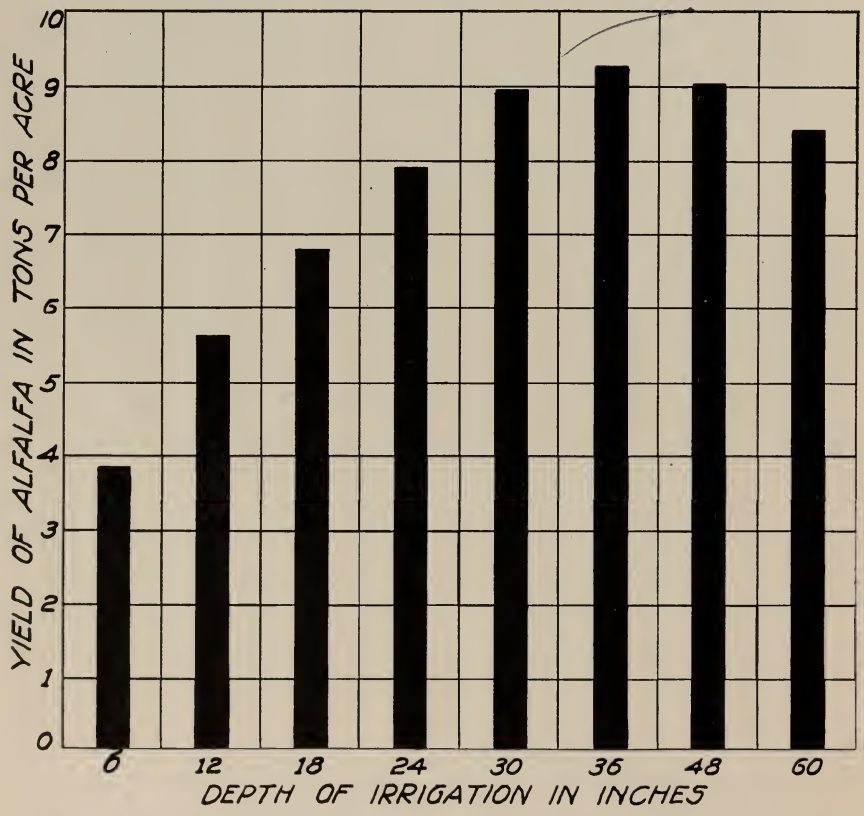

Fig. 4.—Diagram showing results of alfalfa duty-of-water experiments at University Farm, Davis, 1910–1915. Note the maximum yield with an annual application of 36 inches of water. Under the conditions present, the most economical yields were obtained with annual applications of 30 to 36 inches.

TABLE 7

ROOT DISTRIBUTION OF ALFALFA UNDER VARIABLE IRRIGATION TREATMENTS AT DELHI

Depths, *inches*	Six 8-inch irrigations, 1922–25		Six 6-inch irrigations, 1922–25		Three 4-inch irrigations, 1922–24; six 6-inch irrigations, 1925		Twelve 3-inch irrigations, 1922–24; four 6-inch irrigations, 1925	
	Dry wt., *grams*	Per cent of total	Dry wt., *grams*	Per cent of total	Dry wt., *grams*	Per cent of total	Dry wt., *grams*	Per cent of total
Crowns	305.8		371.4		418.6		384.2	
0– 6	396.4	39.1	451.7	37.0	486.9	36.8	511.9	36.2
6–12	201.7	19.9	228.3	18.8	220.3	16.6	276.6	19.6
12–18	135.9	13.4	140.0	11.5	178.1	13.4	164.0	11.6
18–24	103.4	10.3	112.6	9.2	125.2	9.4	128.8	9.2
24–30	62.8	6.2	89.7	7.4	84.6	6.4	84.6	6.0
30–36	44.3	4.4	66.7	5.5	72.0	5.4	82.0	5.8
36–42	29.1	2.9	41.1	3.4	47.9	3.6	52.4	3.7
42–48	18.3	1.8	38.7	3.2	35.4	2.7	38.5	2.7
48–54	12.1	1.2	18.4	1.5	24.4	1.8	32.6	2.3
54–60	8.8	.8	15.5	1.3	22.7	1.7	26.4	1.9
60–66	Hard pan at 60 inches		8.7	0.7	16.4	1.2	14.2	1.0
66–72			5.8	0.5	13.8	1.0	Hard pan at 63 inches	

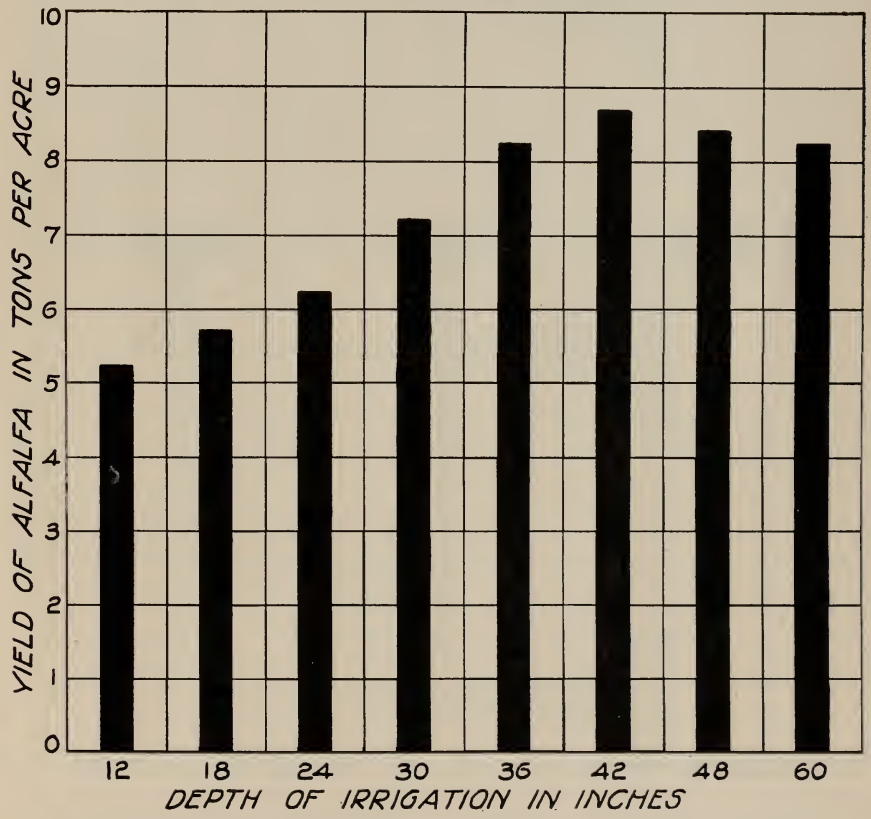

Fig. 5.—Diagram showing results of alfalfa duty-of-water experiments at Delhi, California, 1922–1924. Note the maximum yields with an annual application of 42 inches of water. Under the conditions present, the most economical yields were obtained with annual applications of 36 to 42 inches.

Depth in inches	Irrigations per season: Twelve 2½ inch — Per cent Roots	Soil type	Eight 3¾ inch — Per cent Roots	Soil type	Six 5 inch — Per cent Roots	Soil type
6	33.0	Fine Sandy Loam	42.3	Fine Sandy Loam	37.2	Fine Sandy Loam
12	14.2	" "	15.2	" "	15.9	" "
18	11.9	" "	10.1	" "	12.6	" "
24	8.5	" "	8.1	" "	6.8	" "
30	7.5	" "	5.3	" "	6.9	" "
36	6.3	" "	4.8	" "	4.8	" "
42	4.8	" "	3.9	" "	4.4	" "
48	3.9	" "	2.3	Fine Sandy Loam & Fine Sand	3.0	" "
54	3.1	" "	2.5	Fine Sand	2.6	" "
66	2.7	Fine Sandy Loam & Fine Sand	2.2	" "	2.3	" "
66	2.4	" "	1.8	" "	1.8	" "
72	1.6	Fine Sand	1.5	Gravel	1.7	Fine Sandy Loam and Gravel

Depth in inches	Irrigations per season: Four 7½ inch — Per cent Roots	Soil type	Three 10 inch — Per cent Roots	Soil type	Two 15 inch — Per cent Roots	Soil type
6	33.2	Fine Sandy Loam	34.0	Fine Sandy Loam	35.7	Fine Sandy loam
12	14.6	" "	18.5	" "	15.6	" "
18	11.2	" "	10.3	" "	11.8	" "
24	8.2	" "	8.6	" "	8.2	" "
30	7.0	" "	6.2	" "	5.0	" "
36	5.4	Fine sandy loam and fine sand	6.0	" "	4.3	" "
42	4.8	" "	4.1	" "	3.6	" "
48	3.9	Fine sand	3.0	" "	4.4	Fine sandy loam and fine sand
54	3.3	" "	3.1	" "	3.1	Fine sand and gravel
60	3.3	" "	2.4	Fine sandy loam and fine sandy	3.3	Fine sand
66	2.5	Fine sand and gravel	1.8	Fine sandy loam sand and gravel	2.8	" "
72	2.6	" "	2.0	Gravel	2.2	Fine sand and gravel

Fig. 6.—Diagram showing root distribution of alfalfa under varying irrigation treatments at University Farm, Davis. Note that the root distribution has apparently not been affected by variation in irrigation treatments.

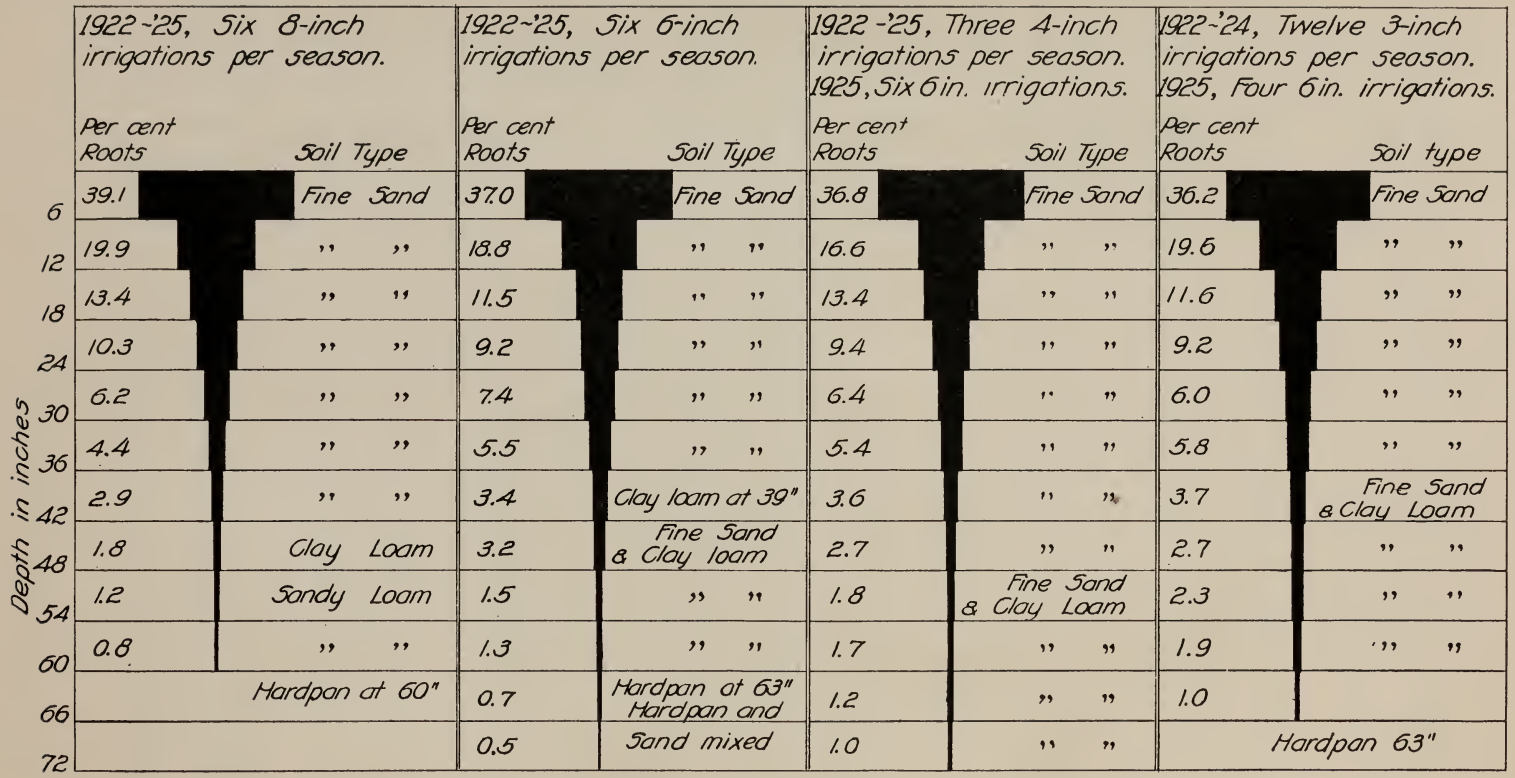

Fig. 7.—Diagram showing root distribution under varying irrigation treatments at Delhi, California. Note that here, as at Davis, the root distribution is unaffected by the irrigation treatments.

Conclusions on Irrigation of Alfalfa at Davis and Delhi.

1. At Davis, the average maximum yield and the average maximum profit were produced with total seasonal applications of 36 acre-inches to the acre, but the difference between the yields produced by 30 inches and those produced by 36 inches is so slight that it is not significant; 30 acre-inches per acre, therefore, can be considered an economic seasonal application under the conditions present.

2. Total depths of less than 24 inches annually, exclusive of rainfall, are insufficient for satisfactory yields. Applications of depths of 48 inches or more annually produce smaller yields than were obtained by applying 36 inches.

3. Variation in the number of irrigations (three to twelve), when a total seasonal depth of 30 inches was applied, caused only small differences in yield. The lighter applications given at more frequent intervals tended to produce the higher yields, but the increases in yields did not warrant the extra labor cost and the inconvenience of applying frequent light irrigations. In loam soils, under Sacramento Valley conditions, a total seasonal application of 30 inches applied in four irrigations represents good irrigation practice for alfalfa. Observations in other localities have shown that the very open or very impervious soils should be irrigated more than once between cuttings.

4. At Delhi, the maximum yields were produced by 42 acre-inches of water to the acre, or by six inches more than was required at Davis—an amount about equal to the difference in rainfall between the two stations.

5. Even in the light soil at Delhi, variations in number of irrigations, providing the same seasonal total was applied, did not materially affect the yield. No doubt the impervious layer at a depth of about six feet prevented the loss of a large part of the water applied in the heavy irrigations, this water being used by the crop in the interval between irrigations.

6. Under field conditions, both at Davis and at Delhi, during a period when the winter rainfall was sufficient to moisten the soil to a depth of at least six feet, and where the depth to the underground water table was more than 15 feet, variation in depth of application or in frequency of irrigation did not affect the root distribution of the alfalfa.

7. On the average, at Davis, 52 per cent of the roots by weight were found in the top foot and 71 per cent in the top two feet of soil. At Delhi, the top foot contained 56 per cent of the roots and the top two feet 78 per cent. Only the top six feet of soil was considered.

INVESTIGATIONS OF MISCELLANEOUS FIELD CROPS AT DAVIS, 1910-1925

From 1912 to 1915, a crop rotation plan was outlined for blocks 1 to 6, shown in figure 1. This plan is shown in the following table.

TABLE 8

ROTATION PLAN OF FIELD IRRIGATION EXPERIMENTS AT DAVIS, 1912–1915

Block	Area, *acres*	Crop			
		1912	1913	1914	1915
1	1.79	Potatoes	Indian corn	Sugar beets	Grain (barley)
2	1.89	Grain (oats)	Sugar beets	Indian corn	Potatoes
3	1.84	Grain (barley and wheat)	Milo maize	Sugar beets	Potatoes
4	2.33	Sugar beets	Grain (wheat and oats)	Potatoes	Indian corn
5	2.64	Indian corn	Potatoes	Grain (barley)	Milo maize
6	1.55	Grain	Grain	Grain	Grain

The cropping followed from 1916 to 1925 is shown in figure 2.

Irrigation of Wheat, Oats, and Barley.—These investigations covered a period of eleven years, beginning in 1910 and terminating in 1921. From 1912 to 1915, the trials were carried on as a part of the crop-rotation scheme covering a period of the four years outlined above.

It was intended that the work with wheat and oats should extend over a longer period than was covered. It was found, however, that a

TABLE 9

PERIOD COVERED BY THE GRAIN INVESTIGATION AND THE GENERAL PLAN OF IRRIGATION TREATMENT

Crop	Year	Irrigation treatment	Remarks
Barley	1910–1916	One, two, or three spring irrigations applied as indicated by crop needs.	1910–1911 on old grain land, 1912–1916 a part of rotation scheme of field crops following alfalfa.
Barley	1913–1921	Summer and fall irrigation before seeding. Each year plot 1 received no irrigation, plot 2 was thoroughly irrigated immediately after harvest and fallowed, plot 3 was irrigated each year prior to fall seeding.	1913–1921 cropped continuously to barley on land on which only grain had previously been raised.
Wheat	1912–1914	One or two spring irrigations applied according to crop needs.	As a part of the rotation of field crops following alfalfa.
Oats	1912–1913	One or two spring irrigations applied according to crop needs.	As a part of the rotation of field crops following alfalfa.

TABLE 10

Results of Spring Irrigation of Barley, 1910–1916 (at Davis)

Season	Seasonal rainfall, *inches*	Plot	Area, *acres*	Number of irrigations	Depth of water applied, *inches*	Yield grain, *pounds per acre*	Ratio grain to straw	Cost of irrigation, *per acre*	Crop of previous year
		6 A	1.25	0	.....	1,160*	1:1.70	.....	Barley
1910	11.90	6 B	0.50	1	3.6	1,480*	1:1.32	$1.08	Barley
		6 C	0.50	2	6.2	1,840*	1:1.86	1.86	Barley
		6 A	0.72	0	.....	850*	1:0.82	.....	Barley
		6 B	0.67	1 (late)	5.6	1,515*	1:0.79	$1.68	Barley
1911	23.18	1 A	0.50	1 (early)	4.3	1,108	1:0.84	1.29	Barley
		1 B	0.50	1 (early)	6.0	2,146	1:0.75	1.80	Cow peas
		1 C	0.50	2	7.0	1,810*	1:0.76	2.10	Barley
		6 A	1.48	0	.....	346	1:0.95	.....	Barley
1912	9.46	3 A	0.49	0	.....	1,040*	1:0.89	.....	Alfalfa
		3 B	0.48	1	7.4	1,285*	1:1.15	$2.22	Alfalfa
		3 C	0.49	2	16.9	1,950*	1:0.94	5.07	Alfalfa
		6 A	1.10	0	.....	448	1:0.95	.....	Barley
1913	8.74	7 A	0.25	0	.....	320*	1:2.75	.....	Corn
		7 B	0.25	1	9.2	2,144*	1:1.50	$2.76	Corn
		7 C	0.25	2	13.4	2,556*	1:2.60	4.02	Corn
		6 A	1.20	0	.....	1,790	1:1.08	.....	Barley
		5 A	0.57	0	.....	2,070*	1:1.20	.....	Potatoes
1914	28.70	5 B	0.19	1	4.0	1,955	1:2.38	$1.20	Potatoes
		5 C	0.19	1	8.0	2,535*	1:1.50	2.40	Potatoes
		5 D	0.19	1	12.0	2,695	1:1.30	3.60	Potatoes
		6 A	0.51	0	.....	1,325	1:1.81	.....	Barley
		1 A	0.26	0	.....	1,970*	1:1.43	.....	Sugar beets
1915	20.05	1 B	0.25	1	3.0	2,085	1:1.28	$0.90	Sugar beets
		1 C	0.25	1	4.5	2,085	1:1.39	1.35	Sugar beets
		1 D	0.25	1	6.0	2,165*	1:1.29	1.80	Sugar beets
		1 E	0.25	1	7.5	2,210	1:1.20	2.25	Sugar beets
1916	20.88	2 A	3.90	0	.....	1,188*	1:2.90	.....	Barley
		2 A	4.00	1	3.2	1,460*	1:3.00	$0.96	Barley

* Yields used in preparing table 11.

TABLE 11

Comparison of Yields After Seasons of Light and Heavy Rainfall (at Davis)

Seasons	Average seasonal rainfall, *inches*	Number of irrigations	Average depth of water applied, *inches*	Average yield* of grain, *lbs. per acre*	Ratio grain to straw	Cost of irrigation per acre
1910, 1912, 1913	10.07	0	.....	840	1:1.78	.....
		1	6.7	1,636	1:1.32	$2.02
		2	12.2	2,115	1:1.80	3.65
1911, 1914, 1915, 1916	23.20	0	.....	1,520	1:1.58	.....
		1	5.2	1,780	1:1.72	$1.56
		2	7.0	1,810	1:0.76	2.10

* In preparing table 11, yields marked with an asterisk (*) in table 10 were used. Results obtained from plot 6 A in 1912–1915 were eliminated, since a fair comparison could not be made between an unirrigated area continuously planted to barley and an unirrigated area under crop rotation.

TABLE 12

RESULTS OF IRRIGATION OF BARLEY LAND BEFORE SEEDING, 1913–1921 (AT DAVIS)

Season	Seasonal rainfall, *inches*	Irrigation treatment	Depth water applied, *inches*	Yield grain, *pounds per acre*	Ratio grain to straw	Cost of irrigation
1913	8.84	None		438	1:0.99	
		One fall irrigation before seeding	12.0	3,306	1:1.25	$3.60*
1914	28.70	None		1,790	1:1.08	
		One fall irrigation before seeding	10.0	2,000	1:1.11	$3.00
1915	20.05	None		1,325	1:1.81	
		One fall irrigation before seeding	9.0	1,330	1:1.75	$2.70
		One summer irrigation before seeding	9.0	1,460	1:2.09	2.70
1916	20.88	None		1,280	1:1.13	
		One fall irrigation before seeding	10.3	1,555	1:1.50	$3.09
		One summer irrigation before seeding	10.3	1,555	1:1.16	3.09
1917	14.11	None		2,505	1:0.81	
		One fall irrigation before seeding	11.3	2,311	1:0.99	$3.39
		One summer irrigation before seeding	11.3	2,258	1:1.33	3.39
1918	9.66	None		714	1:1.67	
		One fall irrigation before seeding	9.2	1,595	1:1.74	$2.80
		One summer irrigation before seeding	9.2	1,515	1:2.56	2.80
1919	19.40	None		2,285		
		One fall irrigation before seeding	10.7	1,330		$3.21
		One summer irrigation before seeding	10.7	1,913		3.21
1920	8.94	None		202	1:2.32	
		One fall irrigation before seeding	10.2	1,332	1:2.00	$3.06
		One summer irrigation before seeding	10.2	1,702	1:1.75	3.06
1921	16.92	None		None†		
		One fall irrigation before seeding	11.2	2,483		$3.06
		One summer irrigation before seeding	11.2	2,935		3.06

* Cost of irrigation (water and labor) figured at 30 cents per acre-inch.

† Climatic conditions did not permit seeding until Feb. 11, and crop did not reach sufficient height to be harvested.

TABLE 13

COMPARISON OF YIELDS OF BARLEY AFTER SEASONS OF LIGHT AND HEAVY RAINFALL (AT DAVIS)

Seasons	Average seasonal rainfall, *inches*	Irrigation treatment	Depth water applied, *inches*	Yield grain, *pounds per acre*	Ratio grain to straw
1913, 1917, 1918, 1920, 1921	11.69	None		772	1:1.45
		Fall irrigated before seeding	10.8	2,205	1:1.50
		Summer irrigated before seeding	10.8	2,102	1:1.88
1914, 1915, 1916, 1919	22.26	None		1,670	1:1.23
		Fall irrigated before seeding	10.5	1,554	1:1.45
		Summer irrigated before seeding	10.5	1,643	1:1.62
All years 1913–1921	16.35	None		1,171	1:1.36
		Fall irrigated before seeding	10.6	1,916	1:1.48
		Summer irrigated before seeding	10.6	1,905	1:1.78

very appreciable portion was shattered each year during heavy north winds, making it impossible to obtain a true measure of the yields, when the crops were allowed to ripen. The plan of the experiments is outlined in table 9. Tables 10 to 15 give the data obtained. A comparison of the yields with the corresponding depths of water applied is made in figure 8.

TABLE 14

RESULTS OF SPRING IRRIGATION OF WHEAT, 1912–1914 (AT DAVIS)

Season	Seasonal rainfall, *inches*	Plot	Number of irrigations	Depth of water applied, *inches*	Yield grain, *pounds per acre*	Ratio grain to straw	Cost of irrigation*
		0	0	.....	564	1:2.10	.....
1912	9.46	1	1	10.0	1,210	1:2.25	$3.00
		2	2	17.6	1,930	1:2.26	5.28
		0	0	.....	127	1:3.89	.....
		1	1	2.0	566	1:5.50	$0.60
		2	1	4.0	1,315	1:2.33	1.20
		3	2	6.0	1,605	1:3.15	1.80
		4	2	8.0	1,632	1:3.00	2.40
1913	8.74	5	2	10.0	1,792	1:3.12	3.00
		6	2	12.0	1,610	1:2.90	3.60
		7	2	15.0	1,240	1:3.64	4.50
		10†	0	.....	1,354	1:1.72	.....
		11†	1	6.8	1,730	1:1.92	2.04
		12†	2	13.0	1,872	1:2.22	3.90
		0	0	.....	1,225	1:3.70	.....
		1	1	4.0	946	1:3.71	$1.20
1914	28.70	2	1	8.0	913	1:4.55	2.40
		3	2	12.0	853	1:4.61	3.60
		4	2	16.0	818	1:4.20	4.80
		5	2	20.0	776	1:4.14	6.00

*Cost of irrigation (water and labor) figured at 30 cents per acre-inch.
† In cow peas, season 1912.

TABLE 15

RESULTS OF SPRING IRRIGATION OF OATS, 1912–1913 (AT DAVIS)

Season	Seasonal rainfall, *inches*	Plot	Number of irrigations	Depth of water applied, *inches*	Yield grain, *pounds per acre*	Ratio grain to straw	Cost of irrigation*
		0	0	.....	437	1:2.25	.....
1912	9.46	1	1	13.2	1,470	1:2.32	$3.96
		2	2	21.8	2,050	1:1.84	6.54
		0	0	.....	0	0	.....
1913	8.74	1	1	8.1	1,016	1:3.86	$2.43
		2	2	15.8	1,508	1:4.33	4.74

* Cost of irrigation (water and labor) figured at 30 cents per acre-inch.

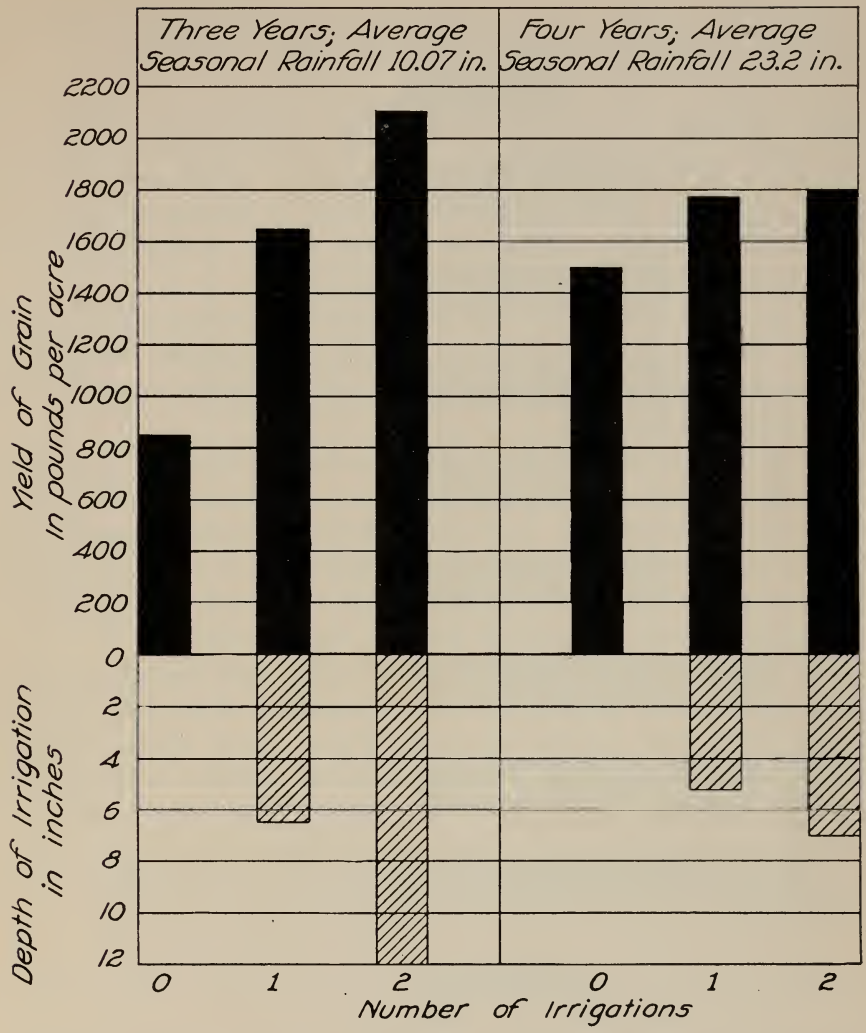

Fig. 8.—Diagram showing results of spring irrigation of barley at University Farm, Davis, 1910–1916. Note the heavy increase in yield due to irrigation in dry years and the comparatively low increases in years of heavy rainfall.

Conclusions on Irrigation of Grain.

1. Under Sacramento Valley conditions, with a seasonal rainfall of 17 inches or more, normally distributed, the increase in grain yields do not warrant irrigation.

2. In years of deficient rainfall, normal yields of grain may be produced with irrigation. The number of irrigations and depth of

water which should be applied in years of deficient rainfall depends upon the rainfall and its distribution, and general weather conditions during the growth of the crop.

3. Under conditions of extreme rainfall deficiency, such as 1910, 1912, and 1913, two irrigations of four to six acre-inches to the acre should be sufficient to produce normal yields. Under conditions of partial drought, especially where a deficiency of rainfall occurs in the late winter and early spring (March and April), satisfactory yields may be obtained through one irrigation.

4. In years of heavy rainfall, irrigation may produce a decrease in yield. However, if this rainfall should be unequally distributed, with a deficiency during March and April, irrigation water may be applied with advantage.

5. Irrigation of grain land before seeding (either in the summer or in the fall just prior to seeding) produces no increase in yields in years of normal rainfall. In years of deficient rainfall, normal yields will be produced by this method of irrigation. In years of drought the average yield produced by this method was one-third greater than the average yields produced in years of normal rainfall.

6. According to the results obtained in the eight years covered by these experiments, there have been six years out of the past eighteen years (1909–1926), at the University Farm, Davis, when irrigation would probably have produced no material increase in yields; six years in which the distribution and amount of rainfall was such that one spring irrigation could have been applied with advantage; and six years in which two irrigations would have been required for full production.

Irrigation of Corn and Grain Sorghum, 1910–1922 (at Davis).—Investigations with these crops were started in 1910 and continued through 1915. In 1922, the work was started again on another tract of the University Farm, but a readjustment of experimental areas forced a temporary discontinuation at the end of that season.

In the production of corn and grain sorghum, standard practices in the preparation of seed bed, seeding, cultivation, and harvesting were followed, the only variable factors being the frequency of irrigation and depths of water applied. In irrigation, the furrow method was used. A thorough cultivation followed each application of water. The water applied was measured by temporary weirs installed in the field laterals.

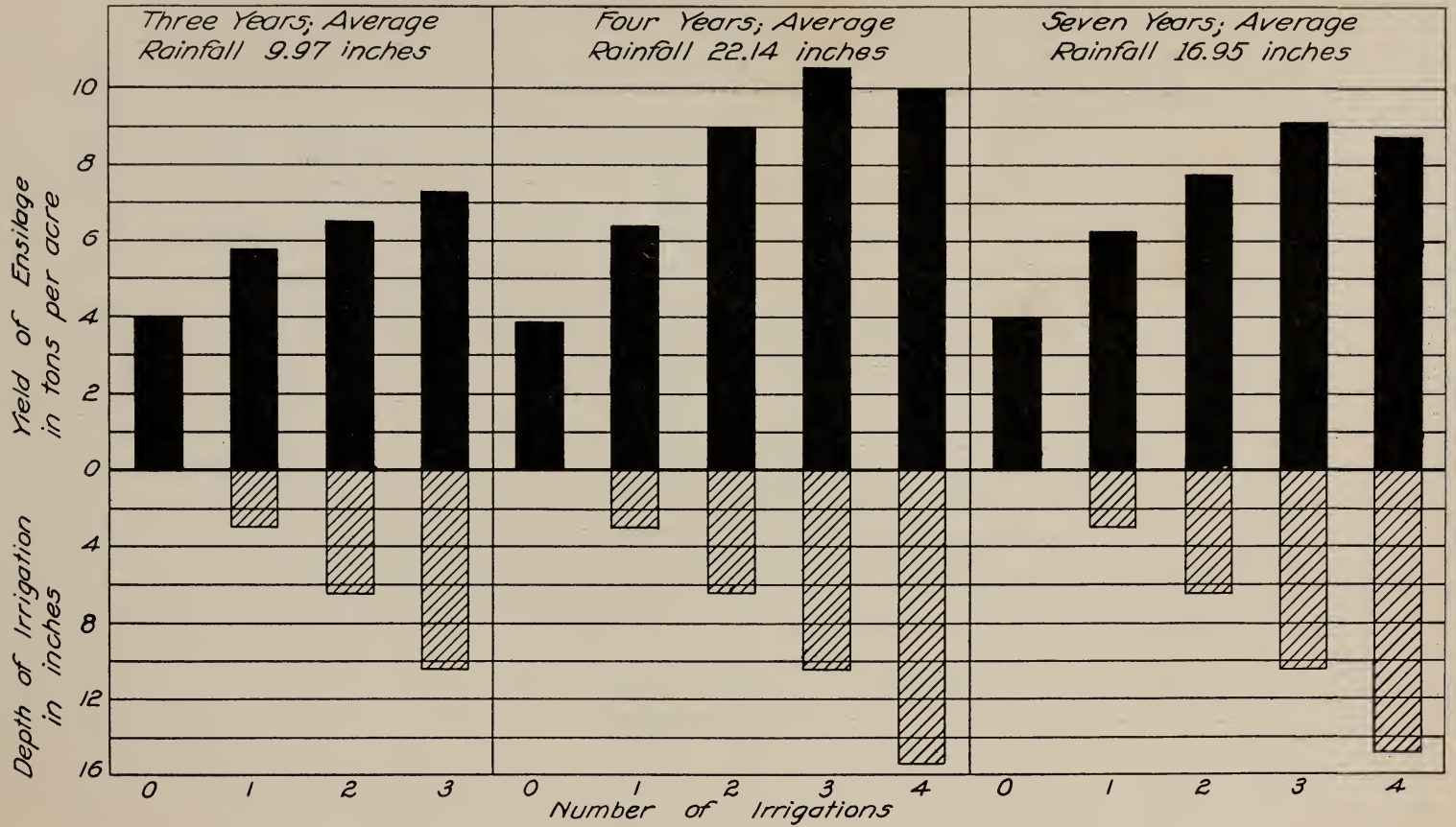

Fig. 9.—Diagram showing results of irrigation of Indian corn grown for ensilage at the University Farm, Davis, 1910, 1915, and 1922. Note that in years of heavy rainfall, also as an average for the seven-year period, the greatest yields were obtained with three irrigations. (Data from table 17.)

The results of yields under varying irrigation treatment in years of light, average, and heavy rainfall are shown in figure 9.

TABLE 16

RESULTS OF IRRIGATION OF INDIAN CORN, 1910–1915 AND 1922 (AT DAVIS)

Season	Seasonal rainfall, *inches*	Plot	Area of plot, *acres*	Number of irrigations	Depth water applied, *inches*	Yield of ensilage *tons per acre*	Cost irrigation*	Crop of previous years
		0	0.67	0	.....	6.91	.....	
1910	11.90	1	0.32	1	3.3	8.84	$1.82	1908, barley
		2	0.32	2	5.3	10.00	3.12	1909, sugar beets
		3	0.67	3	8.0	10.50	4.70	
		0	0.54	0	.....	3.67	.....	1908, barley
1911	23.18	1	0.54	1	2.3	4.86	$1.42	1909, sugar beets
		2	0.54	2	4.7	5.22	2.88	1910, Indian corn
		3	0.54	3	7.1	6.88	4.34	
		0	0.31	0	.....	3.66	.....	
1912	9.46	1	0.35	1	4.0	4.57	$2.10	1909–1911, alfalfa
		2	0.35	2	8.6	5.81	4.42	
		3	0.35	3	14.6	6.60	7.32	
		0	0.26	0	.....	1.54	.....	
		1	0.26	1	3.0	3.80	$1.70	
1913	8.74	2	0.26	2	6.0	3.36	3.40	1909–1911, alfalfa
		3	0.26	3	9.0	4.99	5.10	1912, potatoes
		4	0.26	4	12.0	6.74	6.80	
		5	0.26	5	15.0	7.05	8.50	
		0	0.27	0	.....	3.93	.....	
		1	0.27	1	4.0	7.38	$2.10	
		2	0.27	2	8.0	11.48	4.20	1909–1911, alfalfa
1914	28.70	3	0.27	3	12.0	12.02	6.30	1912, oats
		4	0.27	4	16.0	11.65	8.40	1913, sugar beets
		5	0.27	4	19.2	11.70	9.68	
		6	0.27	4	23.2	11.83	11.28	
		0	0.63	0	.....	4.02	.....	1909–1911, alfalfa
1915	20.05	1	0.56	1	4.0	9.87	$2.10	1912, sugar beets
		2	0.59	2	8.0	12.22	4.20	1913, wheat
		3	0.54	3	12.0	14.15	6.30	1914, potatoes
		50, 51, 52,	0.38	0	.....	4.00	.....	
		47, 48, 49,	0.38	1	3.0	4.96	$1.90	1913–1917, alfalfa
1922	16.62	44, 45, 46,	0.38	2	5.8	6.92	3.32	1918, barley
		19, 20, 43,	0.38	3	11.3	8.35	4.84	1919–1921, corn
		16, 17, 18.	0.37	4	15.7	8.16	8.28	

* Cost of irrigation (water and labor) figured at 40 cents per acre-inch; irrigation furrowing at 50 cents per acre per irrigation.

TABLE 17

SUMMARY AND COMPARISONS OF YIELDS, INDIAN CORN (ENSILAGE) FOLLOWING SEASONS OF LIGHT AND HEAVY RAINFALL (AT DAVIS)

Years	Average seasonal rainfall, *inches*	Number of irrigations	Depth water applied, *inches*	Yields, *tons per acre*	Cost of irrigation per acre*
1910, 1912, 1913 (dry years)	9.97	0	.....	4.04	.....
		1	3.4	5.73	$1.86
		2	6.6	6.40	3.64
		3	10.5	7.36	5.70
1911, 1914, 1915, 1922 (wet years)	22.14	0	.....	3.91	.....
		1	3.6	6.77	$1.94
		2	6.8	8.96	3.72
		3	10.6	10.35	5.74
		4	15.8	9.90†	8.32
1910–1915, 1922	16.95	0	.....	3.98	.....
		1	3.5	6.33	$1.90
		2	6.7	7.86	3.68
		3	10.6	9.07	5.74
		4	14.6	8.85‡	7.84

* Cost of irrigation (water and labor) figured at 40 cents per acre-inch; irrigation furrowing at 50 cents per acre per irrigation.

† Average of 2 years only (1914, 1922). ‡ Average of 3 years only (1913, 1914, 1922).

TABLE 18

RESULTS OF IRRIGATION OF DWARF MILO MAIZE, 1910, 1911, 1913, AND 1922 (AT DAVIS)

Season	Seasonal Rainfall, *inches*	Plot	Area of plot, *acres*	Number of irrigations	Depth of water applied, *inches*	Yield of grain, *pounds per acre*	Cost of irrigation*	Crop of previous years
1910	11.90	0	0.30	0	.....	1,340	.....	1908, barley
		1	0.30	1	3.8	2,680	$2.02	1909, sugar beets
		2	0.30	2	5.5	2,710	3.20	
1911	23.18	0	0.54	0	.....	1,018	.....	1908, barley
		1	0.54	1	1.8	1,565	$1.22	1909, sugar beets
		2	0.54	2	4.6	2,453	2.84	1910, dwarf milo
		3	0.54	3	5.6	2,530	3.74	
1913	8.74	0	0.26	0	.....	.....	.....	
		1	0.26	1	3.0	230	$1.70	
		2	0.26	2	6.0	614	3.40	1909, 1911, alfalfa
		3	0.26	3	9.0	998	5.10	1912, barley
		4	0.26	4	12.0	1,074	6.80	
		5	0.26	5	15.0	1,343	8.50	
		6	0.26	6	18.0	1,842	10.20	
1922	16.63	74, 75, 76,	0.25	0	.....	3,835	.....	
		77, 78, 79,	0.36	1	3.4	4,295	$1.86	1913–1917, alfalfa
		80, 81, 82,	0.37	2	7.1	5,187	3.84	1918, barley
		83, 87, 84,	0.37	3	11.1	5,152	5.94	1919–1921, corn
		85, 86.	0.37	4	13.6	5,747	7.44	

* Cost of irrigation (water and labor) figured at 40 cents per acre-inch; irrigation furrowing at 50 cents per acre per irrigation.

TABLE 19

SUMMARY OF IRRIGATION OF DWARF MILO MAIZE, 1910–1911, 1913, AND 1922

Years	Average seasonal rainfall, *inches*	Number of irrigations	Depth water applied, *inches*	Yield in grain, *pounds per acre*	Cost of irrigation*
		0	.....	1,548	.....
1910, 1911, 1913, 1922.....	15.11	1	3.0	2,192	$1.70
		2	5.8	2,741	3.32
		3	8.6	2,893	4.94

* Cost of irrigation (water and labor) figured at 40 cents per acre-inch; irrigation furrowing at 50 cents per acre per irrigation.

Conclusions on Irrigation of Corn and Grain Sorghum (at Davis).

1. On medium soil types and in years of normal rainfall in the Sacramento Valley, the net irrigation requirement for full crop production should not exceed 12 acre-inches per acre, applied in not more than three irrigations.

2. In years of deficient rainfall the net seasonal irrigation requirement for these crops should not exceed 18 acre-inches, applied in not more than four irrigations.

3. Irrigation of land before seeding is advisable when rainfall conditions have been such that a proper seed bed cannot be prepared, or where there is not sufficient moisture in the surface soil to insure a proper germination of the seed.

4. Under the furrow method of irrigation a normal depth of irrigation is 4 acre-inches per acre for each irrigation.

12*m*-3,'28